

# Scientific Reach of Future Neutrino Oscillations Exps.

Parameter	T2K	T2HK	Reactor	Nova	Nova2	VLBNO
$\Delta m_{32}^2$	✓	✓	-	✓	✓	✓
$\sin^2(2\theta_{23})$	✓	✓	-	✓	✓	✓
$\sin^2(2\theta_{13})^a$	✓	✓	✓	✓	✓	✓
$\Delta m_{21}^2 \sin(2\theta_{12})^b$	-	-	-	-	-	12%
sign of $(\Delta m_{32}^2)^c$	Nova	-	-	T2K	yes	yes
measure $\delta_{CP}^d$	-	Nova	-	<b>Combined</b>	T2HK	$\pm 13^\circ$
N-decay improv.	x1	x20	-	-	-	x8
Detector (KTons)	50	1000	20	30	30	400
Beam Power (MW)	0.74	4.0	14000	0.65	2.0	1.5
Baseline (km)	295 <sup>e</sup>	295 <sup>e</sup>	1	810 <sup>e</sup>	810 <sup>e</sup>	>2500
Detector Cost (\$M)	exists	~\$\$\$	20	165	+ ???	\$\$
Beam Cost (\$M)	exists	\$\$	exists	\$	\$\$\$	400

<sup>a</sup> detection of  $\nu_\mu \rightarrow \nu_e$ , upper limit on or determination of  $\sin^2(2\theta_{13})$

<sup>b</sup> detection of  $\nu_\mu \rightarrow \nu_e$  appearance, even if  $\sin^2(2\theta_{13}) = 0$ ; determine  $\theta_{23}$  angle ambiguity

<sup>c</sup> detection of the matter enhancement effect over the entire  $\delta_{CP}$  angle range

<sup>d</sup> measure the CP-violation phase  $\delta_{CP}$  in the lepton sector; Nova2 depends on T2HK

<sup>e</sup> beam is 'off-axis' from 0-degree target direction

# Comments on Neutrino Oscillations Experiments

- **All parameters of neutrino oscillation can be measured in one experiment**
  - a Very Long Baseline Neutrino Oscillation (VLBNO) at >2000 km
  - the cost of VLBNO is comparable to (or less than) competing proposals
  - the mass of the VLBNO target enables a powerful **Nucleon Decay** search
- **Use of a *broadband neutrino beam at very long distances* is the key**
- **The CP-violation parameter is the most difficult parameter to determine**
  - matter effects interact with CP-violation effects
  - the CP-violation phase  $\delta_{CP}$  has distinct effects over the full 360° range
- **Off-axis beam method requires multiple distances and detectors**
  - all experiments will require of order 10 Snomass years of running
  - each proposed detector will achieve good statistics for most parameters
- **All measured oscillation parameters will be limited to ~1% precision by systematic errors except  $\sin^2(2\theta_{23})$**

# Comments on Neutrino Oscillations Experiments

- A Figure of Merit (FOM) for oscillation experiments is given by:

$$\text{FOM} = [ \sum_i (1 / \sigma_i) ] / [\text{Facility Cost} + 5 \text{ years Operations}]$$

For the experiments discussed, the computed FOMs are:

<u>Facility</u>	<u>Figure of Merit</u>
T2K	1.9
T2K2	0.3
Reactor	4.0
Nova	1.3
Nova2	0.6
VLBNO	0.6